



BHW Technologies (博泓微科技有限公司)



**Advanced RF IC, Antenna, Filter, RF Front-End
and Wireless System Solutions**

BHW Application Note #012

Enabling Cost-Effective High-Precision GNSS Using BHWL161 and Linear-Polarization PCB Antenna

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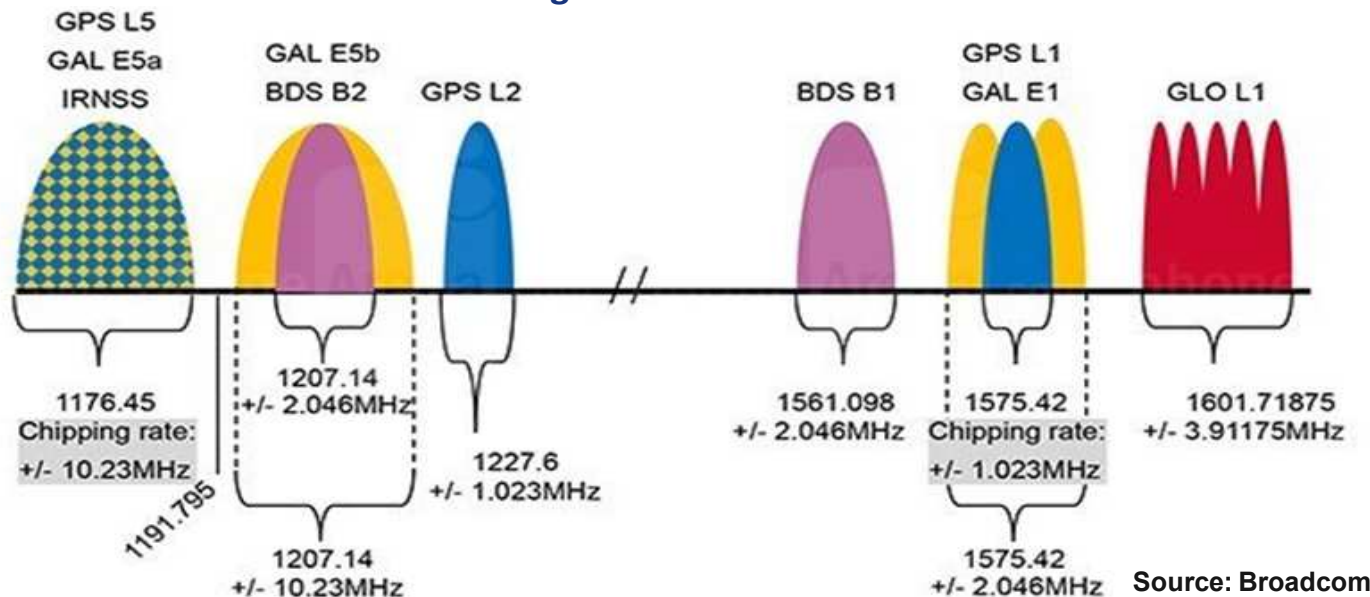
Background: Next-Gen High-Precision GNSS



Technical Challenges for Dual/Multi-Band GNSS:

- Multi/Wide-Band Antenna
- LNA with Low NF and Sufficient Gain over Wideband
- High Input P1dB/IIP3 for Anti-Jamming and Desensitization
- New System Architecture, Implementation and Optimization
- Low Cost for Best-Class Performance
- Typical Ceramic-Based Circularly-Polarized Antennas have Narrow Bandwidth and Limited Radiation Efficiency
- Multiple Ceramic Antennas Need to be Stacked to Achieve Dual/Multi-Band GNSS Operation
- Sufficient Ground Plane Extension underneath the Ceramic Antenna is Needed Typically for Optimal Performance

This AppNote provides theoretical analysis and test results of GNSS C/N0 using circular vs linear polarization antennas, as well as proposal for a high-performance, cost-effective dual/multi-band GNSS architecture using linear-polarization antenna and BHWL161 LNA with potential for monolithic integration of the entire GNSS receiver front-end into a single PCB.



Source: Broadcom

GPS L1 C/A-Code Link Budget



Parameter	Satellite at Low Elevation (EL=5 Degree)	Satellite at Moderate Elevation (EL=40 Degree)	Satellite at Zenith (EL=90 Degree)
Satellite Transmit Power Pt in W	27	27	27
Satellite Transmit Power Pt in dBW	14.3	14.3	14.3
Satellite Antenna Gain (dB)	12.1	12.9	10.2
EIRP toward the Earth (dBW)	26.4	27.2	24.5
Range (km)	25,240	22,020	20,190
Path Loss ($1/(4*\pi*R^2)$) (dB/m ²)	-159.0	-157.8	-157.1
Atmospheric Loss (dB)	0.5	0.5	0.5
Received Power Density (dBW/m ²)	-133.1	-131.1	-133.1
Effective Area of Omni Rx Antenna (dB*m ²)	-25.4	-25.4	-25.4
Receive Power Available from Omni Antenna	-158.5	-156.5	-158.5
Gain of Typical Rx Antenna (dBi)	-4	2	4
C/A-Code Received from Typical Antenna (dBW)	-162.5	-154.5	-154.5
C/A-Code Received from Typical Antenna (dBm)	-132.5	-124.5	-124.5

Source: Pratap Misra and Per Enge, Global Positioning System, Revised 2nd Edition, 2011.

Notes and Comments:

- The above analysis applies to GPS L1 C/A-Code only
- Typical GPS satellite broadcasts 2~4dB more power than the rated Tx power of 27W
- Other GNSS satellites such as BDS has different range (height) and higher transmit power
- The Rx antenna is assumed to have perfect right-handed circular polarization (RHCP)
- Due to limited radiation efficiency of popular GPS Rx antennas such ceramic patches, actual antenna gain might be lower, resulting in slightly lower received signal levels
- **Considering the extremely low received signal levels, it is crucial to use a combination of best-class LNA (with lowest NF and highest linearity) and high-efficiency antenna in order to achieve optimal GNSS system performance (C/N0), as shown in the next page**

C/N0 of RHCP vs Linear Polarization Antenna



RHCP Antenna with Moderate Efficiency LNA with Mediocre NF

C/N0 Calculator for GPS L1 C/A-Code

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Category	Parameter	Value	Unit
Fixed Parameters	Satellite Transmit Power Pt in Watt	27	W
	Satellite Transmit Power Pt in dB	44.3	dBm
	Satellite Altitude Height	20200	km
	Carrier Wavelength	0.1904	m
	k (Boltzmann's Constant)	1.3806E-23	J/K
Almost-Fixed Parameters	Atmospheric Loss	0.5	dB
	Ambient Temp Tamb in Celsius	25	Deg C
	Ambient Temp Tamb in Kelvin	298.15	K
	Satellite Antenna Gain Gt	10.5	dBi
	Antenna Temperature TA	130	K
Variable Design Parameters	System Noise Figure	1	dB
	Rx Antenna Directivity	5	dBi
	Rx Antenna Efficiency	60%	%
	Rx Antenna Pol. Loss (0/3 for Cir./Linear)	0	dB
Calculated Results	Received Carrier Power C	-125.4	dBm
	Effective Temperature Teff	207.2	K
	Effective Noise Density N0 in Watt	2.8606E-21	Watt
	Noise Power Density N0	-175.4	dBm/Hz
	Maximum C/N0	50.0	dB-Hz

Linear Pol. Antenna with High Efficiency LNA with Best-Class NF

C/N0 Calculator for GPS L1 C/A-Code

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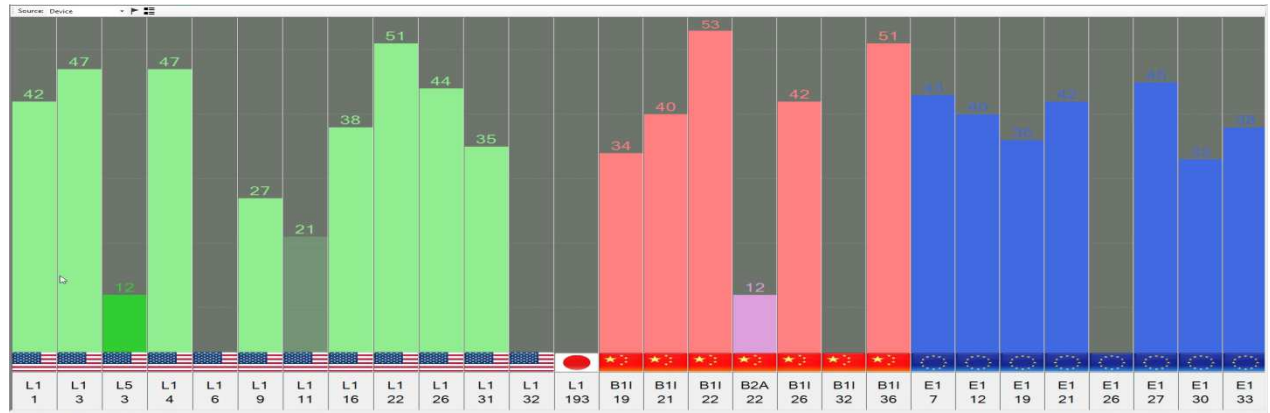
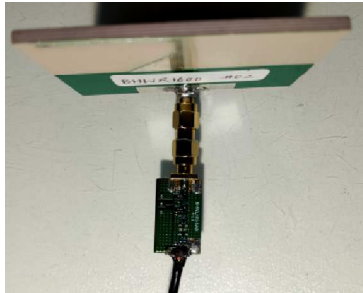
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	Ambient Temp Tamb in Kelvin	298.15	K
	Satellite Antenna Gain Gt	10.5	dBi
	Antenna Temperature TA	130	K
Variable Design Parameters	System Noise Figure	0.5	dB
	Rx Antenna Directivity	5	dBi
	Rx Antenna Efficiency	90%	%
	Rx Antenna Pol. Loss (0/3 for Cir./Linear)	3	dB
Calculated Results	Received Carrier Power C	-126.6	dBm
	Effective Temperature Teff	166.4	K
	Effective Noise Density N0 in Watt	2.297E-21	Watt
	Noise Power Density N0	-176.4	dBm/Hz
	Maximum C/N0	49.7	dB-Hz

- There are only three major parameters that allow design optimization in a typical GNSS receiver: System Noise Figure, Antenna Gain, and Antenna Polarization (3dB loss if linear-polarization antenna is used).
- NF is of paramount importance: Every 0.1dB counts!
- As shown above, a linear-polarization antenna with high efficiency, in combination with LNA with lowest-available NF and best-class linearity, could result in GNSS receivers with comparable or better C/N0 than RHCP ceramic antenna.
- C/N0 of 50~53dB was obtained routinely with BHWL160/L161, due partially to 2~4dB higher transmit power from GNSS satellites.
- BHWL160/L161 GaAs broadband LNAs provide the industry's lowest NF and linearity over full GNSS bands, to help achieve best-class GNSS system performance, using either RHCP or linear-polarization antennas

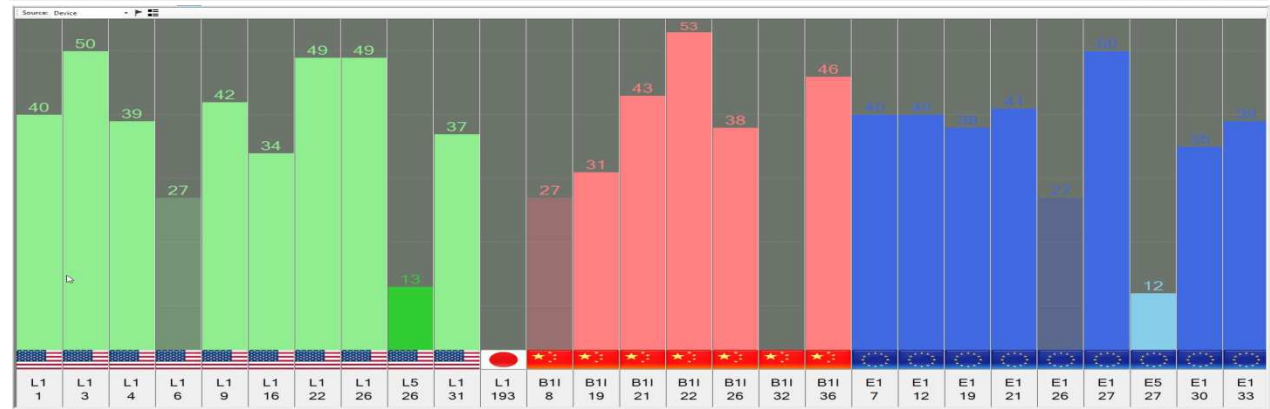
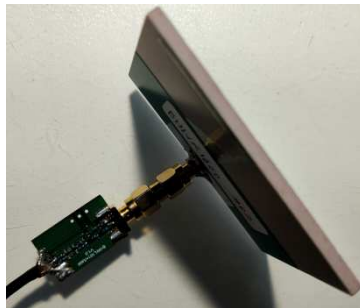
Case Study 2: Dual-Band GNSS Architecture



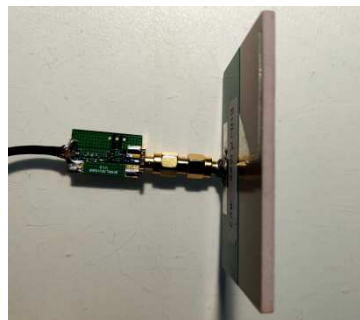
Base (Arbitrary Orientation)
Max. C/N0=53dB



Antenna Rotated by 45 Degree
Max. C/N0=53dB



Antenna Rotated by 90 Degree
Max. C/N0=52dB



BHW RF Front-End AppNote Library



For further information, please email to support@bhwtechnologies.com, or contact your local BHW Sales Rep or Distributor. We will send you the complete AppNote as well as additional related information.

In addition to standard datasheets and EVB/BOM info, BHW publishes an AppNote series that address various topics on RF front-end design and performance over a wide frequency range from 300MHz to 6GHz, as an effort to assist customers in developing cutting-edge, cost-competitive products:

- BHW AppNote #001 - Cross-Over Cascade of BHWM253 to Boost Tx Power and Rx Sensitivity of BLE and 2.4GHz IoT
- BHW AppNote #002 - Accurate Benchmark of GNSS CN0 Using the Power-Splitter Method
- BHW AppNote #003 - Boosting Wi-Fi Tx Power and Rx Sensitivity with BHWA251 and BHWM252
- BHW AppNote #004 - UHF 900MHz RF Front-End Solution Using BHWA251 Half-Watt PA and BHWL160 Sub-1dB-NF LNA
- BHW AppNote #005 - Sub-1GHz Applications of BHWA350 2-in-1 Wideband Fully Matched Amplifier
- BHW AppNote #006 - Low-Noise High-IIP3 LNB Architecture for Dual-Band High-Precision GNSS Using Cascade of BHWL160
- BHW AppNote #007 - UWB RF Front-End Solution Using BHWA350 and BHWM552
- BHW AppNote #008 - High-Power 5.8GHz RF Front-End Solution Using BHWA555 and BHWM552 for ETC, V2X and Wireless Video
- BHW AppNote #009 - 5.8GHz RF Front-End Using BHWA350 and BHWM552 for Wireless Audio
- BHW AppNote #010 - Multi-Constellation GNSS Active Antenna Using BHWL161 Cascade and Single-Fed Dual-Band Antenna
- BHW AppNote #011 - BHWL161 Super-Compact Low-Power Low Noise Amplifier for Range Extension of 2.4GHz BLE, RC and IoT
- BHW AppNote #012 - Enabling Cost-Effective High-Precision GNSS Using BHWL160 and Linear-Polarization PCB Antenna
- BHW AppNote #013 - Enabling Long-Range BLE AoA&AoD for High-Precision Indoor Positioning with BHW GaAs RF Front-End ICs
- BHW AppNote #014 - Designing Ultra Low-Power High-Performance GNSS Products Using BHWL160 GaAs PHEMT LNA
- BHW AppNote #015 - BHWL161 GNSS Full-Band High-Performance LNA in Super-Compact 1x1mm DFN with Relaxed Pin Pitch
- BHW AppNote #016 - Improving GNSS NF Measurement Accuracy Using Broadband LNA BHWL161 as Pre-Amp
- BHW AppNote #017 - High-Efficiency, Low-NF 2.4GHz Front-End Solution for BLE & IoT Using BHWA251 and BHWM252
- BHW AppNote #018 - Optimizing BHWA555 Wideband One-Watt PA for Long-Range 5.8GHz Transmitter Applications
- BHW AppNote #019 - Miniature 2.4GHz RF Front-End with Integrated Chip Antenna and BHWM253 for TWS and IoT
- BHW AppNote #020 - Doubling the Range for BLE Music Streaming with BHWR250L Active Integrated Antenna (AIA)